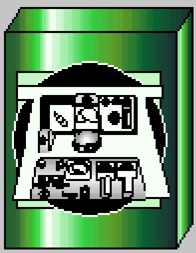
Chapter 15
INFORMATION TRANSFER

15 Information Transfer



Author: Prasad Prabhu

Quote: From a human factors view-point, the information system constitutes the vehicle for carrying out the task goals set for the human-machine system.

INTRODUCTION

From a human factors viewpoint, the information system is the medium or the vehicle for carrying out the task goals that are set for any human-machine system (e.g., the aircraft maintenance system). The "information content" of the information system[1] can be transferred from person to person (via communication), from equipment to person (via displays), from product to person (via inspection), or from person to equipment (via controls).

For example, during a shift turnover meeting in the maintenance hangar, the information transfer between the supervisor and mechanics is through person-to-person communication using speech as the medium of communication. Another example is an engine repair shop situation in which a machine operator sets up and uses his machine to re-size an engine component. Here the information transfer is from the machine to the person via dials, gauges, or computer screens (displays) and from the operator to the machine via knobs, buttons and levers (controls).

When a lead mechanic looks for information on a microfiche or when an inspector looks for the next step of a task in a workcard - the information transfer is from the microfiche or the workcard (display) to the person. Similarly, when an inspector visually inspects an aircraft fuselage the information transfer is from the aircraft (product). Finally, when a mechanic uses an eddy current oscilloscope to look for cracks, the information transfer is from the instrument (display).

You can see that in each of these examples there is an "information interface," either conceptual or physical, that facilitated information "transfer" or "access." During person-to-person communication the interface is conceptual (speech). The other examples are of physical interfaces. Thus, in the case of the operator-machine system the interface consists of the control knobs and dials. In the case of the inspector using a work-card the interface is the workcard in itself. Finally, in the case of the inspector using an eddy-current equipment, the interface is the oscilloscope screen and the buttons and knobs on that instrument.

Information system design can be viewed as the design of this "information interface" such that the information needed to perform a specified task can be efficiently and effectively transferred or accessed by both humans and machines.

Chapter 13 deals in detail with the design of the more conceptual person-to-person interface (communications). This chapter will look at the issues and methods related to evaluating and selecting the physical interface such as controls and displays.

BACKGROUND

The design of the information system, particularly the design of controls and displays, seriously impacts the functioning of the overall system. Improper or inefficient design can lead to errors, hazardous operating conditions, longer training times, frustrations and work delays.

Wilson and Rajan (1995)2 report an incident in which a British Airways helicopter crashed into the sea with the loss of 20 lives out of 26 on board. At the inquest, the pilot admitted that he had not checked the altimeter properly, but also claimed that he did not see a warning light on the altimeter. This warning light should have come on automatically when the helicopter was within 200 ft. of the surface. It was inferred, at the inquest, that the helicopter's control stick can cover part of the instruments depending on the height and build of the pilot. In this case it had, indeed, covered the altimeter warning light and led to the mishap. There are countless other examples like this where the inadequate design of displays and controls has been the cause of errors, incidents and accidents.

Drury and Rangel (1996)3 list instances of poor design of the non-destructive inspection (NDI) equipment interface (controls and displays) for eddy current or ultrasonic inspections. This has resulted in mis-calibration of equipment, longer learning times, and fault detection errors. Similarly, operators of machines in the repair shops can become victims of poorly designed controls on the equipment they use. This can result in delays, poor workmanship and work hazards.

In a study carried out by Patel, Prabhu and Drury (1993)4, most technicians in a maintenance hangar felt that the workcards they used lacked adequate information and could be more readable. Patel et al. (1993)4 showed how poor design of paper-based workcards in hangar inspection led to errors and delays. They proposed information design guidelines that could be used for designing more user-friendly workcards.

Most major transport aircraft manufacturers are using Simplified English5 in their documentation. Chervak, Drury, and Oulette (1996)6 report a study that showed that work cards produced in Simplified English gave improved performance when compared to those prepared in Standard or Non-Simplified English.

Computers are slowly becoming commonplace in the inspection and maintenance work environment. They bring with them the promise of streamlining the workflow and delivering information efficiently. As a result, airlines are making the transition to electronic documentation, automated workcard systems and computerized planning systems. The various software systems on the computers, however, present their own unique problems to the maintenance workers using them. The display that the computer user sees on the screen is called the user interface (UI). The user interface must be designed correctly for the system to be user-friendly and reduce errors and frustration with the system.7

Types of Information

Sanders and McCormick (1993)8 give the following classification of the different types of information:

- Quantitative information: reflects the quantitative value of some variable such as temperature, speed, diameter of a cylinder, etc.
- Qualitative information: presents qualitative aspects of the system such as trend charts, meeting of objectives, etc.
- Status information: reflects the condition or the status of the system such as on-off indications.
- Warning and signal information: is used to indicate emergency or unsafe conditions such as used in aircraft or lighthouse beacons.
- Representational information: is pictorial or graphic information that is symbolic in nature.

Examples of such information are blips on an oscilloscope, a spike on an eddy current meter, charts, blue prints, etc.

- Identification information: is used to identify some situation or object such as using color coded pipes, streamers used to indicate opened pitot tubes on aircraft, etc.
- Alphanumeric and symbolic information: is verbal information in many forms like signs, labels, placards, workcard instructions, etc.
- Time-phased information: reflects information that is controlled in terms of duration of the signal such as Morse code and blinker lights.

Selecting an auditory or visual display will depend on the environmental conditions as well as the type of information that needs to be displayed.

Compatibility Relationships

One of the important concepts necessary for designing controls and displays is that of compatibility. Compatibility is the relationship between system behavior and human expectation. Greater compatibility between the system and the human results in fewer errors, faster learning, and better acceptance of the system. There are four types of compatibility described in human factors literature.[8]

- Conceptual compatibility: is the degree to which codes and symbols correspond to the conceptual associations that people have. Thus an aircraft symbol used to denote an airport on a map will have greater conceptual compatibility than will a green square.
- Spatial compatibility: refers to the physical arrangement in space of controls and their associated displays. Systems having good spatial compatibility will allow the user to easily associate a control with the display that it controls (see Figure 15-1).
- Movement compatibility: refers to the relationship between the movement of displays and controls and the response of the system being displayed or controlled. An example of this compatibility would be a vertical scale in which the upward movement of the pointer corresponds to an increase in the quantity (e.g., temperature or pressure) being displayed (see Figure 15-2).
- Modality compatibility: refers to the fact that certain stimulus-response modality combinations are more compatible with some tasks than with others. For example, a combination of auditory presentation of information and a spoken response from the user might be best for a verbal task.

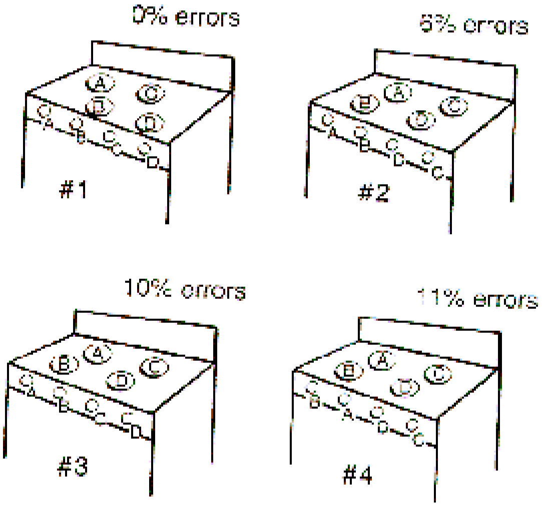


Figure 15-1. Control & burner arrangements and percent user errors for simulated ranges used in the experiment

by Chapanis & Lindenbaum.6 Reprinted with permission from Human Factors, Vol.1, No.4, 1959. Copyright © 1959 by the Human Factors and Ergonomics Society. All rights reserved.

On the other hand, a visual presentation of information and a manual response from the user might be better for a spatial task.

Attention

Information access is inexorably tied with attention --to access information, attention has to be directed at that information. Several types of tasks that involve such direction of attention have been identified in human factors literature.8 These tasks can also be seen in the aircraft maintenance environment.

- Selective attention: The operator or mechanic has to monitor several sources of information to decide whether a particular event has occurred. Examples include a pilot scanning several cockpit instruments looking for a deviant reading.

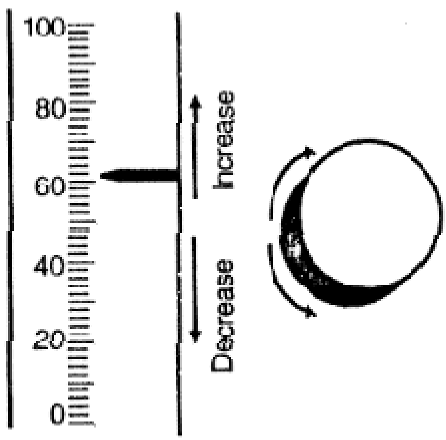


Figure 15-2. Example of movement compatibility: An upward movement of the pointer on the vertical scale corresponds to increased quantity

- Focused attention: The operator has to attend to one source of information and exclude all other sources. Examples include a mechanic reading a maintenance manual in a noisy repair shop.
- Divided attention: Two or more separate tasks have to be performed simultaneously. Examples include driving a vehicle in the airport while carrying out a conversation with the a co-worker.
- Sustained attention: The mechanic has to sustain attention over prolonged periods of time, without rest, in order to detect infrequently occurring signals. Examples include air defense radar operators and security guards viewing a TV monitor, or technicians inspecting many rows of rivets with no corrosion detected.

Traditional Controls and Displays

As explained in the introduction, information interfaces are "points of interchange of information" from machine (system) to humans and vice versa. The information interface traditionally comprises controls and displays. These are the ergonomic interfaces of the human-machine system.10

Displays convey information about the system to the human. The information presented on displays can be either dynamic or static. Dynamic information is subject to change over time whereas static information remains fixed over time. Examples of dynamic information include radar displays, temperature gauges, eddy current oscilloscopes and computer displays. Static information examples include printed forms, labels and maintenance manuals.

Controls constitute the second part of the information interface and can be either electrical or mechanical. A product's controls are the input devices the user manipulates to bring specific responses from the product. They consist of such devices as push-buttons, levers, cranks and knobs. Controls are thus used to provide input to the system (see Figure 15-3).

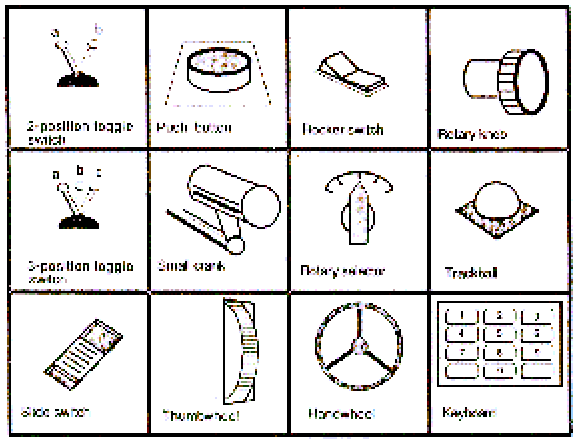


Figure 15-3. Some commonly used controls (from Cushman & Rosenberg, 1984)

With the advent of computers, the traditional difference between controls and displays has become blurred. The computer interface now has both the controls and the displays combined on a single interface (the computer screen). This is in contrast to the more traditional layout where the controls are mechanical and the displays are dials and gauges. In this chapter, when we mention controls it is in the traditional definition of the word and represents issues in the design of mechanical controls.

User Capabilities

User capabilities or characteristics form an important aspect of any evaluation of controls and displays. Some of the relevant user characteristics include vision, hearing, perceptual and motor skills, past experience and anthropometric characteristics.11 The importance of considering user characteristics becomes apparent when you realize that users vary in characteristics, and the control or display might have to be configured to satisfy some constraints imposed by the user's abilities. For example, it is important to assume diminished visual or auditory capabilities for elderly users and that visual or auditory feedback has to be enhanced. Similarly, anthropometric characteristic of the user becomes important when considering requirements of workspace and the ability to reach different controls.

Population Stereotypes

In the "western world," red is understood to mean danger or stop and green means safe or go. Such relationships between system responses or indications and human expectations are called population stereotypes. Population stereotypes are conventions or relationships learned by growing up in a particular culture. For example, in Europe a switch is toggled downward to turn on a light while in the USA the switch is pushed up.

Similarly, engineers have been found to have a different stereotype compared to non-engineers for certain graphical indications like numbering the quadrants on the axis of a graph.12

In the design or selection of controls and displays, care should be taken to ensure that population stereotypes are not violated, since this will increase the probability of errors.

Arrangement of Controls

Controls should be placed where they can be easily reached. The reach envelope varies for males and females. Useful data on the functional reach of humans in different percentiles can be found in most human factors handbooks10,13,14,15 and also in Chapter 4 of this handbook.

General principles have been enunciated for the arrangement of controls. Some of these include: placing critical controls in the most favorable location, arranging controls in functional groups, arranging controls according to the order in which they are used, and minimizing the separation between a control and a display so that they are strongly associated with each other.

These principles and other guidelines for arrangement of controls have been summarized in the GUIDELINES section of this chapter.

Identification of Controls

Unless the functioning of the control is obvious, all the major controls should be identified. Labels may consist of words, a graphic symbol, or a pictogram. Ideally, a control label should indicate the purpose of the control, direction of movement if it is not obvious, and the consequences of moving the control.16 Guidelines for labels are provided in the GUIDELINES section.

Control/Display Relationships

This term refers to how the display responds to an input from the control. This includes: a) the relationship between the direction of control movement and display movement and b) the ratio of the control movement to the display movement (C/D ratio).

For example, when you tune a radio, the clockwise movement of the knob or pushing the button with the "up arrow" label results in the display showing an upward movement of the station numbers. This is called control/display movement compatibility. This type of compatibility greatly reduces the likelihood that the initial movement of the control is in the wrong direction, i.e., "control reversals".11

The C/D ratio affects the ease of performing the task. If this ratio is low it is easy to move from one end of the dial to the other, but fine tuning is tedious. However, if this ratio is high, fine tuning is easy but it may take too long to move between two further spaced points on the dial. The large knob on many volume controls, for example, permits the user to achieve both fine tuning and/or large movement of the dial.

Types of Visual Displays

Displays provide the operator with information about the status of the equipment. Four distinct types of displays are commonly encountered on machines, equipment or vehicles in the maintenance environment:[17]

- "Check" display that indicates whether a given condition exists, e.g., green light indicating normal functioning.
- "Qualitative" display that indicates the status of a variable, e.g., a pointer within a normal range.

- "Quantitative" display that shows the exact value of the information, e.g., temperature gauge.
- "Labels, instructions, warnings" are special displays that are used to provide the user with additional information about the system.

Dials and Gauges

These are mechanical display indicators and are used primarily to provide quantitative information. These displays present information on either a fixed or a stationary scale, using a pointer or reference marker. There are three basic types of mechanical display indicators:18 direct reading counters, moving pointers on a fixed scale and moving scales with fixed pointers (see Figure 15-4).

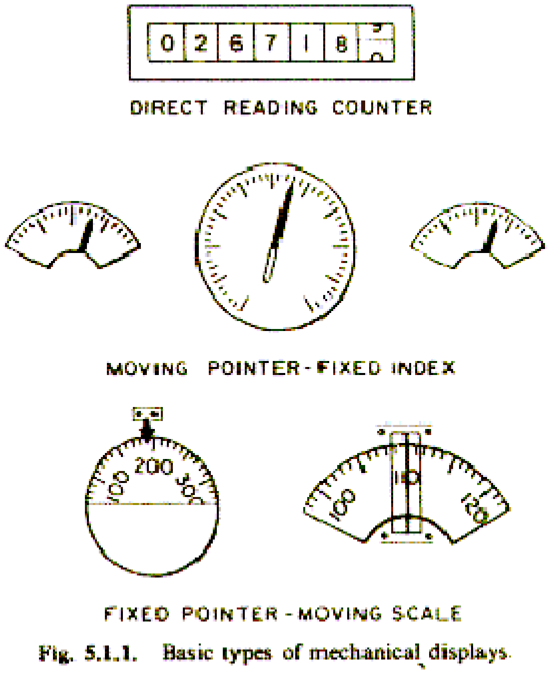


Figure 15-4. Basic types of mechanical displays from Handbook of human factors, Helander, G. Salvendy (ed.), copyright © 1992, John Wiley and Sons. Reprinted by permission of John Wiley & Sons, Inc.

As opposed to digital displays, the dial or gauge also provides some additional information in the form of advance warning, rate of change and/or opportunity to make "cross-dial" extrapolation.16 This is because the pointer position and motion act as an additional cue to what is happening.

Computer-based Information

The aviation industry, like most other organizations, is moving increasingly towards computer-based systems. Computer-based information interfaces can already be seen in numerically controlled or computer controlled machines. The popularity of electronic documentation is bringing about a migration from paper- or microfiche-based information browsers to computer-based document libraries.

In this environment, the ability of the mechanics, inspectors, operators, supervisors, and managers to effectively use computers becomes critical. The software interface on the computer screen allows the user to interact with the system. This interface plays a vital role in determining if the human-computer interaction is successful and efficient. If this interface is poorly designed, it can severely restrict the users' ability to use the system, cause confusion and frustration, create errors and reduce productivity.19

Paper-based Information

In the inspection and maintenance environment there is an abundance of paper-based information in the form of workcards, non-routine cards, maintenance manuals and regulatory documents (FARs, ACs, etc.). Patel, Prabhu, and Drury (1993)4 four basic categories of design issues related to paper-based information: information readability, content, organization, and physical handling factors. A related issue that needs to be considered is the use of a restricted language set or Simplified English.6

Information Readability

This encompasses both legibility and reading ease.

- Legibility addresses issues such as typography, size of letters, case of letters and spacing of letters, words and sentences. Typography deals with justification, bold facing, color coding, underlining and spacing of lines.
- Reading ease is concerned with good writing style and sentence construction. Rules for increasing reading ease are to use simple, affirmative, active sentences and to match the order of words in a sentence to the order of actions to be taken. There are also several indices of readability. The most popular is probably the Flesch Reading Ease Score.20 The reading score derived from this index is a number from 0 to 100 varying from very difficult to very easy. Most word processors like Microsoft Word, WordPerfect, AmiPro, etc. now have reading ease measuring tools that are convenient to use.

Information Content

This addresses the accuracy and completeness of information as well as the presentation method(s) (graphical or pictorial versus verbal or text-based). Appropriate information content relates to the accuracy and completeness of information. To improve the usability of information, it should be:[21]

- Accurate: up-to-date with revisions and updates.
- Complete: regarding what is to be done, where and how it should be done.
- Unambiguous: The information should be clear and have logical and uncontradictory statements.
- Specific and Contextual: it should indicate clearly what is being referred to and within the context of the reader's environment.

Information Organization

This pertains to how the information should be classified and how it should be layered to cater to different classes or types of users. The information organization should be such that it fulfills the needs of both the expert and the novice for a given task. Multiple levels of information can be built into the text. A number of methods can be adopted: use of distinctly separate layers (e.g., a checklist followed by a detailed information sheet); indented paragraphing,22 use of color, graphical anchors or boxes and the use of different print sizes and styles.

Ideally, both the text and graphics should be presented on the same page. Also, the page size should be treated as a naturally occurring module within the document in a physical sense, i.e., if possible, the reader should not have to turn multiple pages to access a related chunk of information.

These and other useful rules have been summarized as guidelines in the GUIDELINES section.

Physical Handling and Environmental Factors

Handling and usage of paper-based information is a critical factor in the maintenance environment.4 In the repair shop environment, paper can get dirty. In maintenance and inspection hangars or during outside line maintenance, environmental conditions like rain, snow and wind can affect the use of paper-based information. Issues like providing well-designed document holders must be considered.

Simplified English

Restricted technical languages are being used in various industries. Some examples are the Caterpillar Fundamental English for the documentation of agricultural vehicles and Simplified English5 for the documentation of procedures on commercial aircraft.

A major evaluation study of SE by Shubert, et al.,23 tested students and found that Simplified English (SE) gave higher comprehension scores and higher scores on ability to find information within the document. A study in the aircraft maintenance environment6 found that comprehension accuracy improved with SE. Also, effectiveness of using SE was most evident when the workcards were difficult and also for non-native speakers of English.

ISSUES AND PROBLEMS

Evaluation criteria, implementation of guidelines, methodologies for design and evaluation, and user input are some of the important issues related to the design of the information system.

Evaluation Criteria

The evaluation criteria for information systems will vary, based on the needs of the particular company as well as the availability of people for the effort. These criteria must be specified, since without them there is no basis for an evaluation.

Design Guidelines

Implementing design guidelines is not always straightforward. For example, in purchasing machinery, the design is not under the control of the buyer. In most cases these are "off-the-shelf" items. Thus, the equipment manufacturer establishes the design criteria for the controls and displays on the equipment. Most vendors try to make their equipment "user friendly" but do not explicitly use human factors data in design.3 However, the user or the buyer can provide input by using a selection criteria that contain some of the guidelines for human factors-oriented design of interfaces (controls and displays) that are outlined in this chapter.

Design Methodology

User performance and satisfaction with equipment or a system depend upon suitability of the displays and controls that form the information interface. A human factors approach to the design and evaluation process is critical in producing controls and displays that are easy to use.

Design and evaluation methodologies in this area are quite empirical in nature. They consist essentially of an iterative application of design principles and guidelines. This chapter provides some general methodologies that supervisors and managers can use to introduce a human factors slant to the information system design process.

REGULATORY REQUIREMENTS

There is no general regulatory guidance related to information system design specifically for controls and displays. However, the topic is fairly well researched and summaries of findings have been compiled. Military and industry standards[24,25,26,27] also provide detailed guidelines. Some of these have been summarized in this chapter.

CONCEPTS

This section defines some of the more important human factors terms and concepts that are encountered during evaluation or selection of the information system interface. Understanding these concepts will help readers apply a human-centric approach to the task at hand. While numerous concepts are associated with evaluating or selecting information displays and controls, the intent of this section is to describe those that are most likely to be used by readers of this chapter.

Attention

Attention is the capacity of the human to direct or channel his or her cognitive resources.

- Selective Attention: the operator or mechanic has to monitor several sources of information to decide whether a particular event has occurred.
- Focused Attention: the operator has to attend to one source of information and exclude all other sources.
- Divided Attention: two or more separate tasks have to be performed simultaneously.
- Sustained Attention: the mechanic has to sustain attention over prolonged periods of time, without rest, in order to detect infrequently occurring signals.

Compatibility Relationships

If any equipment or system is to be used efficiently, it should operate in a manner that is compatible with the user's expectations. Compatibility is the relationship between system behavior and human expectation. Greater compatibility between the system and the human results in fewer errors, faster learning, and better acceptance of the system by humans. The four types of compatibilities described in human factors literature are: conceptual compatibility, spatial compatibility, movement compatibility, and modality compatibility.

Control/Display Ratio

This is the ratio of the movement of the control to the movement of its associated display. It affects the ease of performing the task and the time required to complete it. If this ratio is low it is easy to move from one end of the dial to the other, but fine tuning is tedious. However, if this ratio is high, fine tuning is easy but it may take too long to move between two further spaced points on the dial.

Information Readability

This encompasses both legibility and reading ease. Legibility addresses issues such as typography, size of letters, case of letters and spacing of letters, words and sentences. Reading ease is concerned with good writing style and sentence construction.

Information Content

This addresses the accuracy and completeness of information as well as the presentation of such information (graphical or pictorial versus verbal or text-based). Appropriate information content relates to the accuracy and completeness of information.

Information Organization

This pertains to how the information should be classified and how it should be layered to cater to different classes or types of users. The information organization should be such that it fulfills the needs of both the expert and the novice for a given task.

Population Stereotypes

These are expectations that a majority of the users have about system behavior. These expectations are acquired from day-to-day experiences and training. Thus, population stereotypes are conventions or relationships learned by growing up in a particular culture. For example, in Europe a switch is toggled downward to turn on a light while in the USA the switch is pushed up.

Simplified English

This is a restricted technical language that has been developed for use in the commercial aviation industry for the documenting procedures. Simplified English (SE) has been found to improve comprehension and the ability to quickly locate information.

Traditional Controls and Displays

The information interface comprises controls and displays. Displays convey information about the system to the human. Controls constitute the second part of the information interface and are usually mechanical in nature. A product's controls are the input devices that the user manipulates to bring specific responses from the product. They consist of such devices as push-buttons, levers, cranks and bar knobs.

With the advent of computers, the traditional difference between controls and displays has become blurred. The computer interface now has both the controls and the displays combined on a single interface (the computer screen). In this chapter when we mention controls it is in the traditional definition of the word and represents issues in the design of mechanical controls.

User Capabilities

User capabilities are the characteristics inherent to each user. Some of the relevant user characteristics include vision, hearing, perceptual and motor skills, past experience, and anthropometric characteristics. Users vary in characteristics and the control or display might have to be configured to satisfy some constraints imposed by the user's abilities. If the age, gender, and national origin are known, the data concerning user sensory and motor capabilities and relevant anthropometric data can be obtained from handbooks listed in the reference section.

Usability of Computer Interfaces

The software interface on the computer screen allows the user to interact with the system. Usability refers to the notion of "ease of use" of the system via the interface, i.e., how easy is it to understand the operation of the interface. This interface plays a vital role in determining if the human-computer interaction is successful and efficient. If this interface is poorly designed, it can severely restrict the users' ability to use the system, cause confusion and frustration, create errors, and reduce productivity.

METHODS

Evaluating Traditional Controls and Displays

Task Analysis

Task analysis is the most effective method of evaluating existing controls and displays. The three initial considerations during either evaluation of existing controls and displays or selection from items sold by vendors are:11

- User capabilities
- Control requirements based on the task
- Overall product performance requirements.

Other factors, such as appearance and cost, must be considered after these basic requirements are fulfilled.

Evaluating Computer-based Interfaces

There are many methods available for evaluating computer displays. The following have been selected for ease of use and relevance to the airline maintenance environment. These methods can be used with relatively little experience in human-computer interface design. However, we suggest that a person well-versed in the area of human-computer interaction (HCI) be consulted to develop the guidelines needed to use some of these methods. Alternatively, the guidelines outlined in the GUIDELINES section can be used as a starting point.

User Feedback

This method is appropriate when a system is already in use. The users of the system are given a formal questionnaire that elicits their opinions of the system. The questionnaire should be structured to ask questions about the interface design (see GUIDELINES) and also task-based questions (i.e., how does this system address their current task). Space should also be left for open-ended answers to encourage the mechanic or technician to make any comments or suggestions about the system. The answers to the questionnaire then can be analyzed to identify any user problems with the interface.

User Testing

This is probably the best and most reliable method of evaluating a user interface. It involves observing the user using the system. Specific tasks can be chosen so that all the important aspects of the system functionality are covered. All observations are noted and can then be analyzed to find mismatches between control and display design and the user's actions. Video taping of the user while operating the system is also an effective analysis method.

Heuristic Evaluation Method

This method can be used while designing the interface for a system that is being developed in-house. It involves having usability specialists judge whether each element of the computer interface conforms to established usability principles. These principles are normally referred to as heuristics. Usability specialists are people with experience in the human-computer interaction field who have been involved in user interface specification or design.

Guideline Review Method

This method can be used while evaluating a system being considered for purchase. It involves using a comprehensive list of usability guidelines to check user interface for conformance to these guidelines. This method can be used only if the system's usability guidelines have been developed in advance.

Designing/Evaluating Paper-based Information

Checklist Approach

This approach can be used to evaluate existing workcards and other documentation. Patel et al. (1993)4 have provided detailed guidelines for the design of maintenance workcards. These guidelines are generally applicable for most paper-based information systems.

Iterative Design Approach

The documentation design process has to involve both the writer and the users for whom this material is being written. The process should be iterative and allow feedback from users to be input into the design of the workcards, maintenance manuals, and other such documents.

READER TASKS

Maintenance supervisors and planners will have occasion to provide input to the information system design or re-design process in several ways. Their input will be valuable and appropriate when it is related to either evaluating the existing system, evaluating new equipment being purchased, or specifying the information system standards. It is vital that human factors input be provided for these tasks, since this input will affect the eventual use of the system or the equipment.

At this point, it should be noted that designing controls and displays or software interfaces are tasks that need expert help. Activities like specifying detailed interface standards, as well as doing an intensive evaluation, also need additional expertise beyond what can be provided by reading this chapter. However, the methods and guidelines in this chapter can be used to identify situations where expert help may be needed.

Evaluating Existing Interfaces

This is one area where significant results will be seen from a human factors-based information system re-design process. The goal of this process should be to identify any human factors-related mismatches in the existing information transfer system.

Traditional Controls and Displays

Evaluation involves examining the control and displays on existing machinery and equipment. A task analysis, as described in the METHODS section, should be conducted on how workers use the current system (see also Chapter 1).

Computer Interfaces

For software interfaces, the user feedback method or the user testing method described in the METHODS section can be used. As part of this analysis, readers should verify that they are adhering to the appropriate guidelines from the GUIDELINES section. This approach will unearth issues underlying the use of the equipment. These issues can then be addressed either in terms of re-designing the interface or identifying specific training needs.

Evaluating New Equipment Interfaces

When the decision is made to buy or lease new equipment or software, supervisors and planners should address the issue of whether information interfaces on this new purchase meet human factors design requirements.

A simple checklist-based approach using the guidelines in this chapter can form the basis of an effective evaluation of equipment. It also can help in the comparative evaluation of multiple equipment or software. All other things being equal (based on priority or criticality), the equipment having an interface with the best match to human factors design guidelines should be selected.

Specifying Interface Standards

As in the case of facility design or workplace design, specifying the human factors requirements for purchased or newly-developed equipment and software will significantly influence the overall usability of the system. Purchasing agents may not be aware of the human factors issues involved. When products are purchased, usability may be compromised due to a natural tendency to give more weight to the capital costs. However, equipment or software interfaces that do not adhere to human factors guidelines have hidden costs over the period of use in terms of greater probability of errors, higher training costs and reduced productivity.

Interface standards should be made available to purchasing agents. Overall, these issues have to be addressed as part of a selection and evaluation philosophy that explicitly identifies interface standards and then uses them when purchasing new equipment or software.

Developing Paper-based Documentation

Paperwork is one of the realities of the maintenance environment. Even with the push for on-line computer-based documentation, paper-based documents remain the major information source. A well-designed paper-based document makes the transition to an electronic environment easier.

Procedures have to be developed for consistent, high-quality documents. The documentation division or department in the company has to work with maintenance people to identify the issues and problems in the current paperwork and find solutions. All procedures and solutions should be standardized so that mistakes are not repeated.

GUIDELINES

General Guidelines

In many cases, the selection of the most appropriate sensory modality (visual, auditory, tactile, etc.) is pre-determined by the type of task. Table 15-1 provides some broad guidelines for selecting between audio and video presentations.

Sanders and McCormick (1993)8 identify some guidelines that can be used to improve information system interfaces.

Following these guidelines can enhance human performance in tasks demanding different types of attention. These guidelines are described in Table 15-2.

Table 15-1. Guidelines for auditory and visual information.

AUDITORY PRESENTATION	VISUAL PRESENTATION
Simple message	Complex message
Short message	Long message
Message will not be referred later	Message will be referred later
Message deals with events in time	Message deals with location in space
Message calls for immediate action	Message does not call for immediate action
Visual system is currently over-burdened	Auditory system is currently over-burdened
Information receiving location is too bright or too dark and cannot be changed.	Information receiving location is too noisy and cannot be changed
Person's job requires moving about continually	Person's job allows remaining in one position

*Source: Deatherage, 1972, p.124.*28

Table 15-2. Guidelines for information system based on types of attention (adapted from Sanders and McCormick, 1993)8

A. Selective Attention Tasks

1. If multiple displays (e.g., meters) have to be scanned for information, then use as few displays as possible.

2. To direct attention more effectively, provide the worker with information about the relative importance of the information on the different displays that are being scanned.

3. Train the person to scan displays by developing an optimal scanning pattern.

4. Put the visual displays that have to be scanned close together to reduce long eye movements and reduce stress.

B. Focused Attention Tasks

1. When multiple sources of information compete for attention and the person will have to focus on one, make these competing sources as distinct as possible. For example, if two different sources of information have to be shown, present one visually and one verbally.

2. Reduce the number of competing information sources. Reduce the level of sound in the repair shop if reading information is a critical part of the job.

3. Make the information display that is of interest, larger, brighter, louder or more centrally placed than the other competing information channels. This relates to labeling critical information, designing signs, and highlighting important information on the computer screen.

C. Divided Attention Tasks

1. Provide workers with information about the relative priorities of the tasks so that an optimum strategy for dividing attention between the tasks can be formulated.

2. Try to keep the difficulty level of tasks demanding divided attention as low as possible.

3. When physical or manual tasks (e.g., steering wheel control, typing) are time-shared with memory tasks, try to build a very high proficiency (learning) into the manual task to lessen the demands on memory.

D. Sustained Attention Tasks

1. Provide appropriate work-rest schedules and task variation (i.e., different tasks)

2. Increase the conspicuity of the rarely-displayed signal or information.

3. Provide adequate training to make clear the nature of the signal to be identified.

4. Improve motivation by emphasizing the importance of the task being performed.

5. Maintain environmental factors such as noise, temperature, humidity and illumination at reasonable levels.

Evaluating/Selecting Traditional Controls and Displays

Task analysis should be used to evaluate existing controls and displays.

- First, the users' capabilities should be defined (see GUIDELINES). This allows incorporation of important aspects such as physical capabilities, anthropometric requirements and cognitive requirements in the design or selection of the control and display interface.
- Next, we should determine the characteristics of the tasks users will perform using the equipment or system of interest. This is done by performing a detailed task analysis of the users' tasks. Task analysis provides important information on the number of controls that are needed and also the desirable characteristics for each control. For example, if the task requires a control for making continuous adjustments, then task analysis will show the range of adjustments that will be needed.11
- Using the information on user capabilities and task requirements we can evaluate and select controls and displays. The guidelines on control arrangement, functional location, population stereotypes, etc., that have been summarized in the **GUIDELINES** section may be used at this stage. Aesthetics and cost considerations now also can be considered for making the final decision.

Specific guidelines for control and displays have been summarized in this section. These can be used as part of a checklist to evaluate existing controls or to aid in selecting new equipment.

User Capabilities

User capabilities should be considered before selecting any control or display. These include vision and hearing, past experience, and anthropometric characteristics.

If many elderly workers are present, diminished visual and auditory capabilities should be assumed. Consideration should be given to increasing the size of control labels. If auditory signals are associated with any control, then they must be loud enough to be heard by persons with significant hearing loss.

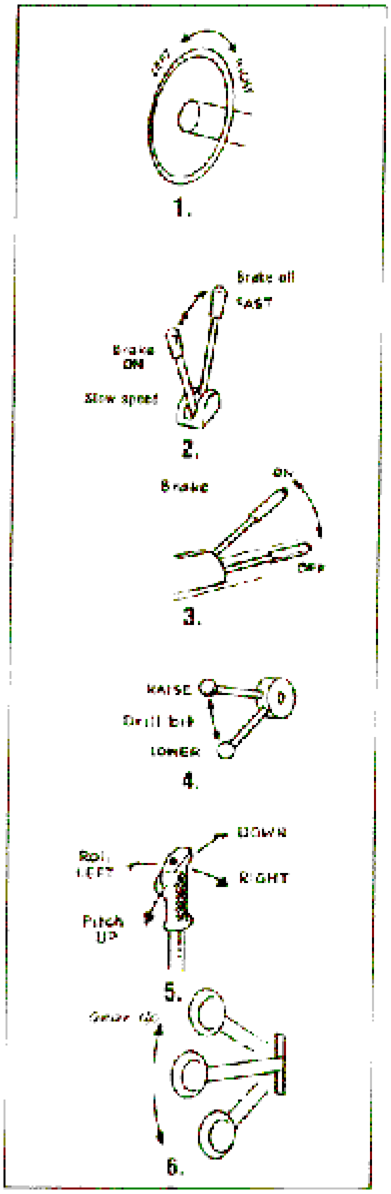
Past experience with similar controls significantly reduces the decision demands of operating equipment. In the absence of such experience, suitable training should be considered.

Anthropometric characteristics of users should be considered when arranging controls. This includes making an allowance for clothing and protective equipment. For example, if gloves will be worn while operating controls, then controls must be large enough and placed apart enough for easy operation.

Functional Usefulness

Controls should be selected for their "functional usefulness." This includes the following guidelines:[17]

- The direction of operation of a control (see Table 15-3 and Figure 15-5) should be compatible with stereotypical or common expectations (e.g., ON control is pushed or pulled, not turned to the left).
- The control type should be compatible with stereotypical or common expectations. A pushbutton or a toggle switch should be used to turn on a light, not a rotary knob (see Table 15-4).
- Operations requiring fine control and small force should be done with the hands, while gross adjustments and large forces should usually be exerted with the feet.



EXPECTED CONTROL MOTIONS

Figure 15-5. Stereotypical or commonly expected control motions from <u>Human factors design handbook</u>, Woodson, W. et al.,16 copyright © 1992, The McGraw-Hill Companies

- The control should be safe in that it cannot be operated inadvertently or operated in false or excessive ways.
- The force or torque applied by the operator for actuation of the control should be kept as low as is feasible.

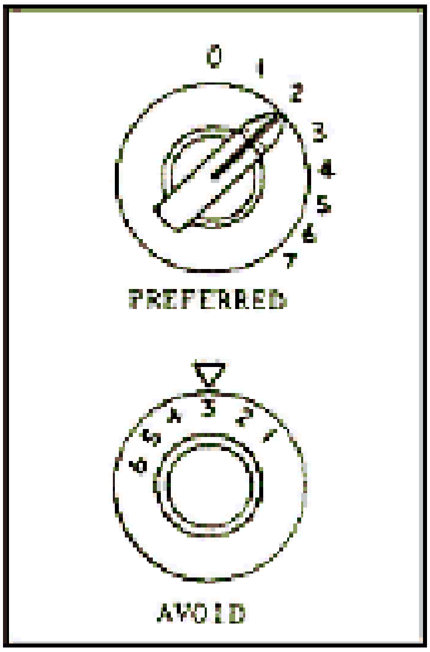


Figure 15-6. Moving scales cause "reversed" control motion from Human factors design handbook, Woodson, W. et al.,16 copyright © 1992, The McGraw-Hill Companies

Table 15-3. Control movements and expected effects (adapted from Kroemer, et al., 1994)17

Expected Effects	Preferred Control Movements
On	Up, Right, Forward, Clockwise, or Pull (with push-pull switch)
Off	Down, Left, Rearward, Counter-clockwise, or Push (with push-pull switch)
Right	Right, Clockwise, Forward (if left movement has been chosen as back)
Left	Left, Back, Counter-clockwise (if right movement has been chosen as clockwise)
Raise	Up, Rearward
Lower	Down, Forward
Retract	Rearward, Up, Pull (with push-pull switch)
Extend	Forward, Down, Push (with push-pull switch)
Increase	Forward, Up, Right, Clockwise
Decrease	Rearward, Down, Left, Counter-clockwise.

Table 15-4. Control-effect relations of common hand controls (adapted from Kroemer, et al., 1994)17

Expected Effect	Preferred Hand Controls
Select ON/OFF	Key-lock, Toggle switch, Push button, Rocker switch
Select ON/STANDBY/OFF	Push button, Bar Knob, Lever, Slide
Select OFF/MODE 1/MODE 2	Bar knob, Lever, Slide
Select one of several related functions	Push button, Toggle switch, Rocker switch
Select one of three or more discrete alternatives	Bar Knob, Slide, Toggle switch
Select operating conditions	Toggle switch, Push button, Rocker switch, Lever
Engage or Disengage	Lever
Set value on scale	Round knob, Slide, Continuous thumbwheel
Select value in discrete steps	Push button, Bar knob, Discrete thumbwheel, Slide
Continuous or fine adjustments	Crank, Round knob, Track ball.

Arrangement of Controls

The following rules apply to the grouping or arrangement of controls (adapted from Kroemer, et al., 1994).[17]

- *Locate for ease of operation*.
Orient controls with respect to the operator. If the operator has different positions, the controls and control panels, preferably, should move with the operator so that in each position their arrangement and operation is the same for the operator.
- *Primary controls first*
The most important and most frequently used controls should have the best positions for ease of operation and reaching.
- *Group related controls together*
Controls that have sequential relations, that are related to a particular function, or that are operated together, should be arranged in functional groups (together with their associated displays). Within each functional group, controls and displays should be arranged according to operational importance and sequence.
- *Arrange for sequential operation*.
If operation of controls follows a given pattern, controls should be arranged to facilitate that sequence. The common arrangements are left-to-right (preferred) or top-to-bottom.
- *Be consistent*
The arrangement of functionally-identical or similar controls should be the same from panel to panel.

- *Dead-Man control*
This control should be used to counter the situation in which the operator may become incapacitated

and either let go of a control or continue to hold onto it. The "dead-man control" design should either return the system to a non-critical operational state or shut it down.

- *Guard against accidental activation*

Use methods to guard critical controls against accidental or inadvertent activation.

- *Pack tightly but do not crowd*

Often it is necessary to place a large number of controls into a limited space. In such cases, use the data available on the minimal separation distances for various types of controls (see Table 15-5).

Table 15-5. Minimal separation distances (in mm) for hand controls (adapted from Kroemer et al., 1994, Boff and Lincoln, 1988)[17,29]

	Keylock	Bar knob	Thumb-wheel	Push-button	Toggle Switch	Rocker Switch	Knob	Slide Switch
Keylock	25	19	13	13	19	19	19	19
Bar Knob	19	25	19	13	19	13	25	13
Thumb-wheel	13	19	13	13	13	13	19	13
Push button	13	13	13	13	13	13	13	13
Toggle Switch	19	19	13	13	19	19	19	19
Rocker Switch	19	13	13	13	19	13	13	13
Knob	19	25	19	13	19	13	25	13
Slide Switch	19	13	13	13	19	13	13	13

Prevention of Accidental Activation

Accidental activation of controls can, in some cases, cause injury to the person, damage to the system, or performance errors. The following methods can be used to prevent such incidents:

- Locate and orient critical controls so the operator will be unlikely to contact it in the normal sequence of operations.
- Recess, shield, or surround the control by physical barriers.
- Provide interlocks between controls so that either the prior operation of a related control is required, or an extra movement is necessary to operate the control.
- Provide extra resistance so that unusual effort is required to actuate the control.
- Provide a means of "locking" so the control cannot pass through a critical position without delay.

Guidelines for Displays

Some general guidelines for displays are as follows:[17,18,30]

- Arrange displays so the worker can locate and identify them easily without unnecessary searching.
- Group displays functionally or sequentially so the worker can use them easily.
- Make sure that all displays are properly illuminated, coded and labeled according to their function.
- Use the simplest display needed for the task. The more complex the display, the more time it takes to read and interpret the information it provides. This will also increase the probability of errors.
- Avoid the temptation to make displays merely attractive and/or startling at the expense of being readable and interpretable.
- Optimize the visibility and conspicuity (ability to attract attention) of the display.

Choosing Dials and Gauges

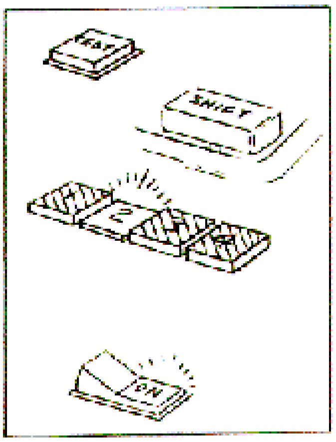
As mentioned earlier, there are three basic types of mechanical display indicators or dials and gauges:18 direct reading counters, moving pointers on a fixed scale, and moving scales with fixed pointers. Each of these dials and gauges has advantages and disadvantages (see Table 15-6 and Figure 15-6) depending on the type of information to be displayed:[16,18,31]

- Counters are best suited to display quantitative information that does not change rapidly over time. A counter-type display is also preferred to set specific values.
- Qualitative information is best displayed using a fixed scale with a moving pointer
- A fixed-scale-type of display needs the most panel space as well as the availability of constant illumination across the entire scale. A moving scale saves space because the entire scale does not have to be displayed. Also, only a small section of the scale has to be illuminated. A counter-type mechanical display is the most economical in terms of space and illumination.
- Whenever possible, avoid the use of dials and gauges in which double pointers or scales are used.
- Always place the pointer at the bottom or to the right of the scale.
- The spacing of scale graduations must be great enough so that the observer can discriminate between one mark and another, and also see the relation between the scale marks and the pointer. The observer should be able to read the display scale without taking an inordinate time peering at the instrument.

Table 15-6. Preferred mechanical display indicators for specific types of task (Helander, 1992)18

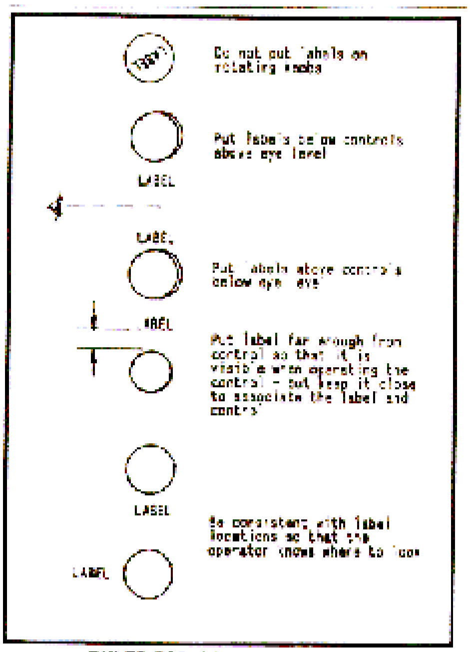
Use of Display	Type of Task	Display Typically Used for	Type of Display Preferred
Quantitative Reading	Exact numerical value	Time from a clock, rpm from tachometer	Counter
Qualitative Reading	Trend; rate of change	Rising temperature	Moving Pointer
Check Reading	Verifying numeral value	Process control	Moving Pointer
Setting to	Setting target bearing;	Compass	Counter or Moving

desired value	setting course		pointer
Tracking	Continuous adjustment of desired value	Following moving target with cross hair	Moving Pointer
Spatial Orientation	Judging position and movement	Navigation aids	Moving Pointer or Moving Scale



EXAMPLES OF WORD LABELS

Figure 15-7. Examples of word labels from <u>Human factors design handbook</u>, Woodson, W. et al.,[16] copyright © 1992, The McGraw-Hill Companies



RULES FOR CONTROL LABELING

Figure 15-8. Rules for control labels from <u>Human factors design</u>

handbook, Woodson, W. et al.,16 copyright © 1992, The McGraw-Hill Companies

Light Signals

Light signals are used to indicate the status of a system (ON/OFF, warning, etc.). some of the common color coding conventions are:

- White Signal: has no correct/wrong implications but may be used to indicate that certain functions are ON.
- Green Signal: indicates that the equipment is in satisfactory condition or that it is switched ON.
- Yellow Signal: is used to advise that a marginal condition exists and that alertness is needed, or caution should be exercised or that checking is necessary.
- Red Signal: is used to alert operator of system malfunction, failure, or error -- successful operation of the system is not possible.
- Flashing Red Signal: denotes an emergency condition that requires immediate action to avert impending personal injury, equipment damage, etc.

Labels

Labelsare often needed so that the worker may locate, read, or identify controls or displays. Labeling has to be done such that the information on the label is available to the user accurately and rapidly (see Figure 15-7, 15-8). The following guidelines can be used:[17]

- *Orientation*: The label and the information on it should be oriented horizontally for reading.
- *Location*: The label should be placed on or very near to the item that it identifies.
- *Standardization*: Placement of all labels should be consistent throughout the equipment and system.
- *Equipment Functions*: A label should primarily describe the function of the labeled item.
- *Abbreviations*: When abbreviations are used their meaning should be obvious to the user. Use common, well-known abbreviations only. Use capital letters in abbreviations and omit periods.
- *Brevity*: The label text should be as concise as possible without distorting the intended meaning.
- *Familiarity*: Words on the labels should be, if possible, familiar to the observer.
- *Visibility and Legibility*: The observer should be able to read the label easily and accurately at the anticipated worst illumination levels.

Warnings and Signs

It is preferable to have "active warnings," i.e., a sensor that notices inappropriate use and an alerting device that warns the operator of the impending danger.17 However, in most cases "passive warnings" are used because they are cheaper and more easily provided. The labels and signs for such warnings must be carefully designed by following the most recent government laws and regulations, national standards, and available human engineering information. The following guidelines summarize some important considerations that apply to the design of warnings and signs,30 (See Chapter 3).

- *Conspicuity*: The sign should attract attention and be located where people will be looking. Three main factors determine the amount of attention that people devote to a sign - prominence, novelty, and relevance.

- *Emphasis*: The most important words should be emphasized. For example, a sign might emphasize the word "danger" by using larger characters and borderlines.

- *Legibility*: May be enhanced by increasing the contrast of the characters against the background (e.g., black letters on a white background have more contrast than yellow letters on a blue background).
- *Intelligibility*: Make clear what the hazard is and what may happen if the warning is ignored. Use as few words as possible, avoid acronyms and abbreviations. Tell the observer exactly what to do.
- *Visibility*: The warning or sign should be visible under all expected viewing conditions, including day and night viewing, bright sunlight, etc.
- *Maintainability*: Materials for the warning or sign must be chosen to resist the aging and wear due to environmental factors like sun, humidity, heat, cleaning detergents, etc.
- *Standardization*: Use words and symbols common in the maintenance environment, whenever such words exist.

Evaluating/Specifying Computer Interfaces

The METHODS section lists several methods such as user feedback, user testing, heuristic evaluation and guideline review methods. All these methods to an extent are aimed at getting user (worker) feedback. For example, in the "user feedback" approach, a questionnaire is used to elicit opinions from the users about the current interface. The questionnaire should use guidelines for human-factors-oriented interfaces (as described in the next section) to get user feedback.

Similarly the guideline review method and, to a lesser extent, the heuristic evaluation method will make use of checklists based on general usability principles. User testing is the only method that does not explicitly use a checklist based on guidelines. However the guidelines can be used to ensure that all aspects of user interface problems are covered.

Guidelines for usable computer interfaces are available from various sources.7,19,32 Prabhu et al. (1996)33 have compiled some of these guidelines and included them as part of the user interface specifications for data entry systems for the Flight Standards Information System (FSIS) of the FAA. These general guidelines can be followed while evaluating computer interfaces or while making decisions on interface specifications.

System Status Visibility

Current system status should be clear to users. This can be achieved by implementing the following:

- Feedback should be provided on user actions within reasonable time.
- The user should have little difficulty understanding what the current screen represents.
- There should be an informative and visible title on each screen/dialog box/menu.
- Items should be labeled so that each option in a list of available options is clear to the user.
- A consistent and explicit interface metaphor should be used throughout the system.
- Required information should be easy to find on the screen.
- The user should be clear about what information to enter and in what format.

User Compatibility

The interface design should be compatible with the conventions and expectations and relevant to the user's work environment -- the system should speak the user's language.

- Words, phrases and concepts familiar to the users should be used both in the interface and in the help facility.

- Icons, symbols, graphs, etc. should be easy to understand.

User Control

The user should feel in control of the system.

- Undo and redo functions should be supported to ease error recovery.
- A clearly marked "emergency exit" should be provided on each screen to leave an unwanted state.

Consistency and Standards

The look and feel of the system should be consistent at all times on the different screens. The users should not have to wonder about usage.

- Platform conventions should be followed. For example, if Windows 95 is used then follow conventions specified by this platform.
- Care should be taken to display similar information (e.g., control button for exit or next page, etc.) at the same locations on different screens.
- There should be a consistent method of entering information and selecting options.

Error Prevention/ Recovery

The system response to user actions should be designed to be user-friendly. This is achieved by the following:

- Design and development should focus on minimizing the probability of user errors.
- Error messages should be designed to help users recognize, diagnose and recover from any errors.
- Error messages should use plain language, indicate the problem, and suggest a solution.

Minimalist Design and Efficiency of Use

The computer screen should not contain irrelevant or rarely-needed information.

- Any controls that are not available on a particular screen should be disabled.
- It should be easy to return to the main menu from all screens.
- Data input should be minimized by pre-filling information wherever possible.
- It should be easy to return to the previous screen or state.

User Support/ Help

Help should be informative, easy to search, and focused on the user's task.

- The system should provide relevant, context-sensitive and fast help.
- Help should list the specific steps to be carried out.
- Unless additional functionality is required by the application, use the help facility provided by the operating system that is being used. For example, if using Microsoft Windows 3.11, use the MS Windows' WINHELP as the help engine.

Developing Paper-based Documentation

The following procedure is suggested for revising or designing text.[4,34]

1. Gather all the technical information.
2. Write the procedure or text.
3. Read the text through quickly.
4. Read the text through again, but this time ask yourself: Who is this text for and can the intended reader understand this text?
5. Read the text through again, but this time ask yourself: How can I make this text easier to follow? What changes need to be made to help the reader?
6. Global or major changes that you might consider are (use the guidelines suggested by Patel et al., as a checklist):
   - Re-sequence parts of the text.
   - Re-write sections in your own words.
   - Add in examples.
   - Change older examples to newer or better ones.
   - Delete parts that seem confusing.
7. Text changes that you might consider are (use the guidelines suggested by Patel et al., as a checklist):
   - Use simpler wording.
   - Use shorter sentences.
   - Use active rather than passive voice.
   - Substitute positives for negatives.
   - Write sequences in order.
   - Space numbered sequences or lists down the page.
8. At this stage you might consider using a readability formula such as the Flesch Reading Ease Index.
9. Give the procedure to the user (or group of users) to evaluate understanding.
   - These evaluations can be informal using a questionnaire or interview.
   - Ask readers to circle on the text those areas, sentences, or words they think readers less able than themselves will find difficult.
   - Alternatively, use formal testing to find readability scores.
10. Integrate user feedback to finalize the document.

Patel, Prabhu and Drury (1993)4 have provided specific guidelines for designing paper-based workcards in the maintenance environment. However, these guidelines are equally applicable to other documents, such as maintenance manuals, non-routine cards, etc. (See Table 15-7, pages 15-32 through 34). In addition, Drury, *et al.* (1997) have developed and tested the Documentation Design Aid (DDA)35,36, which is available in both paper- and computer-based forms.

Simplified English5 should be considered in some situations to improve documentation usability (See Table 15-8). Some guidelines for adopting Simplified English are adapted from Chervak, Drury, and Oulette, 1996.[6]

- If a large portion of your technicians are non-native speakers of English, consider using SE.
- Consider using SE for complicated workcards for both native and non-native speakers of English.
- SE will not adversely affect performance in any case .

Table 15-7. Guidelines for design of paper-based documentation for aircraft maintenance Cont. (adapted from Patel, et al. 1993)4

INFORMATION READABILITY

Typographic layout

- Use primary cues as much as possible. These are vertical spacing, lateral positioning, paragraphing and heading positioning.
- If space usage is premium, then use secondary cues. These are boldfacing, italics, underlining, color coding and capital cueing in a decreasing order of preference.
- Use full justification of textual material.
- Use a consistent typographic layout throughout the document.

Sentence, Word, and Letter

- Use of sentence conventions:
- Boundary conventions
  - Capitalize first letter in a sentence.
  - Use a final punctuation mark.
  - Place a question mark at the end of a question.
- Use of word conventions:
  - Do not use all capitals format, use both upper and lower case.
  - For word division at the end of a line use a hyphen.
  - Initial capitalization for all proper nouns.
- Use of letter conventions
  - Use a type face like Helvetica that has no redundant features.
  - Avoid using a generic dot-matrix typeface.

Printing Quality Standards

- Develop and implement rules for changing printer ribbons, toner boxes, etc. to ensure consistent print quality at all times.

Table 15-7. Guidelines for design of paper-based documentation for aircraft maintenance Cont. (adapted from Patel, et al. 1993)4

INFORMATION CONTENT

Appropriate Content

- Provide information such that it supports the technician's personal goal to "read quickly and also understand the information."

- Provide accurate information.
- Information should be complete -- provide information on what is to be done, where, how, in what order or sequence, which specific items to pay attention to and references to additional sources of information
- Information should be up-to-date with revisions.
- Achieve a balance between brevity, elaboration and redundancy of information.

Graphical or Pictorial Information

- Present spatial information in a pictorial format. Spatial information deals with location of parts, orientation of objects, etc. Avoid using text alone for such information.
- Make sure that the text assists the graphics and not vice versa on a pictorial page.
- Use a consistent format for figure layout and number.
- The figure views should be as the technician sees it, from a fixed distance/scale, e.g., 5 feet viewing distance.
- Avoid using perspective part drawings as figures.
- For all figures and attachments in a work card, include back references to the workcard that originally referred the figure.
- Use consistent and correct technical drawing terminology, e.g., avoid using terms "section" and "view" interchangeably.
- Provide different graphics for mirror imaged tasks, e.g., avoid using the same graphics for both the left and right wing inspection tasks.
- Differentiate close-up views from distant views by giving appropriate scaling information.

Table 15-7. Guidelines for design of paper-based documentation for aircraft maintenance Cont. (adapted from Patel, et al. 1993)4

INFORMATION ORGANIZATION

Classification of Information

- Distinguish between directive information, reference information, warnings, cautions, notes and methods.
- Directive information should be broken into the command verb (e.g., check), the objects (e.g., valves, hydraulic lines), and the action qualifiers (e.g., for wear, for frays).
- Each chunk of directive information should not include more than two or three related actions per step. This eliminates errors. For example: "remove 10 bolts, remove cover" is acceptable but "check brake valves, brakes, tires and cables" is not acceptable.

Information Layering

- Wherever possible, provide multiple levels of information to cater to the needs of both experts as well as novice technicians. Provide more elaborate information for novices and more concise information for the experts performing the same tasks.

Other Organizational Issues

- The task information on work cards should be ordered/sequenced in the natural order in which tasks would be carried out by most maintenance technicians.
- The page should act as a naturally occurring information module, i.e., it should contain a fixed number of tasks and avoid carry over of tasks across pages. Each task that begins on a page should preferably end on the same page.

PHYSICAL HANDLING AND ENVIRONMENTAL FACTORS

- Size of the work card should be handy. Avoid using large technical drawings.
- The entire work card should not be excessively heavy.
- Provide localized reading lights in poor lighting conditions.

Table 15-8. Examples of Maintenance Workcards written in simplified & non-simplified English (Chervak et al.)[6]

Simplified English	Non-Simplified English
Functionally Check Hydraulic System L/R/C Reservoir Pressurization Check Valve for Proper Operation.	Functionally Check Hydraulic System L/R/C Reservoir Pressurization Check Valve for Proper Operation.
1. Reservoir Pressurization Check Valve Test	1. General
A. General	A. This procedure contains a test of the check valves which retain air pressure in the hydraulic system reservoirs after pneumatic power is removed. This test applies to each main hydraulic system.
(1) This procedure does a test of the check valves which keep air pressure in the hydraulic system reservoirs after the pneumatic power is removed. This is a test of each main hydraulic system.	
(2) The check valve is in the manual depressurization valve on each system reservoir.	B. The reservoir pressurization check valve is located in the reservoir manual depressurization valve installed on each system reservoir.
B. Equipment	2. Equipment
(1) Air pressure Gage - 0 to 100 psi range - commercially available	A. Air pressure gage - 0 to 100 psi range.
(2) A source of clean, dry air or nitrogen, that is controlled from 0 to 100 psi maximum pressure - commercially available	B. Regulated source of clean dry air or nitrogen, 0-100 psi maximum pressure.
C. References	3. Referenced Procedures

(1) 06-41-00/201, Fuselage Access Doors and Panels	A. 06-41-00/201, Fuselage Access Doors and Panels
(2) 24-22-00/201, Electrical Power - Control	B. 24-22-00/201, Electrical Power - Control
(3) 36-00-00/201, Pneumatic Control	C. 31-41-00/201, EICAS
	D. 36-00-00/201, Pneumatic Control

WHERE TO GET HELP

The Human Factors and Ergonomics Society (HFES) is an excellent source of information for information regarding information system design

Human Factors and Ergonomics Society

PO Box 1369

Santa Monica, CA 90406

Phone: (310) 394-1811

Fax: (310) 394-2410

Web site: http://hfes.org

Email: hfes@compuserve.com

More specific help related to design and evaluation of controls and displays on equipment, may be obtained from the HFES technical group:

Human Factors and Ergonomics Society

Industrial Ergonomics Technical Group

Contact through the HFES main office (see above)

The Association For Computing Machinery (ACM) has a special interest group (SIG) on Computer Human Interaction (CHI) called SIGCHI. This can provide useful information on the design and testing of computer interfaces:

ACM SIG Services

1515 Broadway

New York, NY 10036

Phone: (212) 626-0613

Fax: (212) 302-5826

Another source for equipment design information is the Crew System Ergonomics Information Analysis Center (CSERIAC). This is a Department of Defense Information Analysis Center and will conduct literature searches. It also publishes pre-researched reports which are for sale.

CSERIAC Program Office

AL/CFH/CSERIAC Bldg. 248

2255 H Street

Wright Patterson AFB, OH 45433

Phone: (513) 255-4842

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EXAMPLE SCENARIOS

The scenarios presented below represent some of the typical kinds of information-oriented situations that one can expect to encounter in the workplace. The purpose of including these scenarios in the *Guide* is to demonstrate how the authors foresee the document being used. For each scenario, we describe how the issues raised in the scenario can be resolved. There is usually more than one way to approach these issues, so the responses given below represent only one path that users of the *Guide* might take.

As a general rule, always start to look for information by using the Search function. There will be instances that you already know where required information is located. However, unless you frequently use specific sections of the *Guide*, you might miss information pertaining to the same issue located in more than one chapter. The Search will allow you to quickly search all chapters simultaneously.

Scenario 1 - New Technology Isn't Working

You have just purchased a new eddy current oscilloscope for your non-destructive inspection department. This is a state of the art equipment and incorporates the latest technology. However, your inspectors are having a hard time learning to use it. Calibrating the instrument seems to take longer than the other oscilloscopes that you have. Your inspectors also complain that instrument is difficult to use. Operating errors such as pushing the wrong button or selecting the wrong setting are reported.

Issues

1. How do you find out if these problems are due to the design of the "controls and display" interface.
2. If the problem is indeed due to a poorly-designed "control and display" interface, will training help?
3. What are the measures you could take to minimize the loss of productivity and probability of errors when using this equipment?

Responses

1. There is always a learning curve associated with using a new instrument incorporating new technology. But some of these problems could be due to a poorly-designed information interface. The METHODS section describes how you can evaluate controls and displays. Define the user capabilities and the characteristics of the task.

With a description of user capabilities (see GUIDELINES), find whether the difficulties are faced by both experienced and inexperienced inspectors. Use the guidelines to see if the controls on the equipment have been designed according to human factors principles. If these guidelines have been violated, then there is high probability that the problems that inspectors are facing are due to a poorly designed interface.

2 .Since you have already bought the equipment, your first response would be to incorporate some type of training. This might not always work. While doing the task analysis, if you found that inexperienced inspectors have more difficulties than experienced AMTs, it would indicate that training on the equipment would help. However, if experienced inspectors are also having trouble operating this equipment, then you will have to take other measures.

3. List the mismatches that exist in the control/display interface by using guidelines. This gives you information on what type of errors or problems to expect. Correct any mismatches that you can. If labeling is the problem, make new labels. However, there will be mismatches that you cannot correct. For example, if related controls are not grouped together, then you can expect that there will be delays in operating this equipment.

Similarly, if population stereotypes have been violated, then there is a good chance that the wrong control movement will be selected. Make sure that mismatches will not cause a serious problem. If this is the case, the equipment needs to be replaced. Also, use the identified mismatches in the training program so that inspectors understand why certain errors might happen.

Scenario 2 - Work Slowed Down by Workcards

In the engine repair shop, paperwork errors have become a constant source of frustration. You notice that mechanics are missing final sign-offs, as well as sign-offs indicating compliance with EO's , EA's, etc. Also, you observe that your maintenance technicians avoid referring to workcard instructions. Finally, when they do refer to workcards the technicians find that information is not always clear and available.

Issues

1. Are the sign-off errors due to the workcard design?
2. How do you evaluate the current workcard and identify solutions that make the workcard more usable?
3. How can you justify the cost of re-designing workcards?

Responses

1. Sign-off errors can be caused by poor workcard design. Use the guidelines on information readability and information organization to determine if the sign-off section of the workcard follows good human factors principles of information design. You might find non-compliance with guidelines such as "eliminate use of all illogical and self-contradictory statements" or "task information should be ordered/sequenced in the natural order in which the task would be carried out by most inspectors." Such mismatches will indicate that these sign-off errors can at least partially be attributed to workcard design.

2. A method for revising paper documents has been described in the METHODS and GUIDELINES sections. In addition, consider using a questionnaire to get feedback from multiple AMTs about the problems that they are facing with the current workcard. You are bound to find some very interesting problems as well as solutions from the AMTs. Use the guidelines for designing workcards outlined in Table 15-7 (See pages 13-32 through 34). Remember to keep the user -- the technician - continually involved in their design process.

3. This chapter has not explicitly discussed cost justification issues. However, poorly-designed workcards or other documentation can lead to an obvious decrease in productivity, cause compliance problems, and be a source of frustration. If possible, gather data on the paperwork errors that have occurred. Also take an official sampling of worker opinion of workcards through a survey. This material can be used to push for a paperwork re-design effort.

Scenario 3 - Computer software should be usable

Your company has just initiated a software effort to put some of the paperwork on-line. You keep hearing about new systems that will streamline work flow. However, you have not seen anybody come to the floor and talk with the inspectors or the technicians.

Issues

1. Should you be more involved in the software design process?
2. How can you evaluate the software system to see if it will be user friendly?
3. How can you get a feel of the training effort that will be necessary for this system?

Responses

1. Of course you should. It is a critical human factors assertion that the user should be actively involved in the design of any system that affects how he or she works. In case of computer systems, the design of the user interface is very important for the eventual usability of the system. You should take up the issue and insist that software designers interact with your inspectors and technicians to understand the work environment.

2. The guideline review method explained in the METHODS section is a good approach to conducting such an evaluation. The GUIDELINES section outlines the general principles that make a system user friendly. These can be used to make an informal but effective evaluation of the software interface. Any concerns that arise should be conveyed to the systems developers for making the necessary changes.

3. This chapter doesn't address the impact of poor interface design on training requirements. However it is obvious that the less the interface adheres to human factors guidelines, the more difficult it will be to teach and learn. Particular attention should be paid to the availability of on-line help, on-line tutorials, and good error messages.

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